Even more interesting is the fact that the elements don't matter. We can take a circuit and measure all the voltages. We can then make element-for-element replacements and, if the topology has not changed, we can measure a set of currents. The sum of the product of element voltages and currents will also be zero!

3.17 Electronics

So far we have analyzed **electrical** circuits: The source signal has more power than the output variable, be it a voltage or a current. Power has not been explicitly defined, but no matter. Resistors, inductors, and capacitors as individual elements certainly provide no power gain, and circuits built of them will not magically do so either. Such circuits are termed electrical in distinction to those that do provide power gain: **electronic circuits**. Providing power gain, such as your stereo reading a CD and producing sound, is accomplished by semiconductor circuits that contain transistors. The basic idea of the transistor is to let the weak input signal modulate a strong current provided by a source of electrical power the power supply to produce a more powerful signal. A physical analogy is a water faucet: By turning the faucet back and forth, the water flow varies accordingly, and has much more power than expended in turning the handle. The waterpower results from the static pressure of the water in your plumbing created by the water utility pumping the water up to your local water tower. The power supply is like the water tower, and the faucet is the transistor, with the turning achieved by the input signal. Just as in this analogy, a power supply is a source of constant voltage as the water tower is supposed to provide a constant water pressure.

A device that is much more convenient for providing gain (and other useful features as well) than the transistor is the **operational amplifier**, also known as the op-amp. An **op-amp** is an integrated circuit (a complicated circuit involving several transistors constructed on a chip) that provides a large voltage gain **if** you attach the power supply. We can model the op-amp with a new circuit element: the dependent source.

3.18 Dependent Sources

A **dependent source** is either a voltage or current source whose value is proportional to some other voltage or current in the circuit. Thus, there are four different kinds of dependent sources; to describe an op-amp, we need a voltage-dependent voltage source. However, the standard circuit-theoretical model for a transistor contains a current-dependent current source. Dependent sources do not serve as inputs to a circuit like independent sources. They are used to model **active circuits:** those containing electronic elements. The RLC circuits we have been considering so far are known as **passive circuits.**